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AUTHOR Rodriguez, Beatriz T. Font
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ABSTRACT

This study examined the tensions that surfaced as a result of a teacher's transition from traditional to reform-oriented pedagogy while participating in the Mathematics Teacher Development Project and using the Investigations in Number, Data, and Space curriculum. In particular, the purpose of this study was: (a) to explore the relationship that develops between a teacher's learning in a teacher development project and her implementation of an innovative curriculum as it may influence the resolution of dilemmas that arise as she attempts to reform her practice; and (b) to identify features of the teacher development project and the curriculum that appear to have impacted the teacher's practice. The study was conducted as a case study with a practicing teacher (Maria) who had already taught at the elementary level for 10 years. At the time of the study, Maria participated in the fifth (last) semester of a reform-oriented teacher development program and was using a reform-oriented curriculum for the first time. This study indicates that an effective teacher education program utilized in conjunction with a reform-oriented curriculum provides teachers with learning opportunities that promote the transformation of their traditional ways of teaching. However, their learning creates tensions and dilemmas resulting from specific conflicts (e.g. decision making about the focus of lessons) between their evolving, reform-oriented understandings and the traditional ways to which teachers are accustomed. Contains 22 references. (Author/CCM)

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An Investigation Into How a Teacher Uses a Reform-Oriented Mathematics Curriculum

Beatriz T. Font Rodriguez

The University of Texas - Austin

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Abstract

The study reported herein examined the tensions that surfaced as a result of a teacher's transition from traditional to reform-oriented pedagogy while participating in The Mathematics Teacher Development Project and using the Investigations in Number, Data and Space (TERC, 1998) curriculum. In particular the purpose of this study was (a) to explore the relationship that develops between a teacher's learning in a teacher development project and her implementation of an innovative curriculum as it may influence the resolution of dilemmas that arise as she attempts to reform her practice and (b) to identify features of the teacher development project and the curriculum that appear to have impacted the teacher's practice. The study was conducted as a case study with a practicing teacher (Maria) who had already taught at the elementary level for ten years. At the time of the study, Maria participated in the fifth (last) semester of a reform-oriented teacher development program and was using a reform-oriented curriculum for the first time. This study indicates that an effective teacher education program utilized in conjunction with a reform-oriented curriculum provides teachers with learning opportunities that promote the transformation of their traditional ways of teaching. However, their learning creates tensions and dilemmas resulting from specific conflicts (e.g. decision making about the focus of lessons) between their evolving, reform-oriented understandings and the traditional ways to which the teacher is accustomed.

An Investigation Into How a Teacher Uses a Reform-Oriented Mathematics Curriculum

In the context of reform outlined by The National Council of Teachers of Mathematics (NCTM) in their Curriculum and Evaluation Standards for School Mathematics (Standards) (1989), the National Science Foundation has funded the development of several curricula geared toward helping teachers implement this reform. These curricula are characterized by an increased emphasis on mathematical understanding, reasoning, and problem solving, while at the same time reducing emphasis on the memorization of rules and computational procedures (Remillard, 1997).

Ball (in press) contends that a fertile place to help reform a teacher's practice would be to change the curricula they follow. The challenge to implement reform-oriented curricula must be met by teachers, who are "themselves products of the very system the current reforms seek to change" (Ball, in press, p. 38). Oftentimes these teachers resort to traditional ways of implementing reform-oriented curricula, using the activities and manipulatives in a procedural manner. Ball and Cohen (1996) noted that in order for teachers to implement mathematics reform, they must not only learn about the mathematical content pertinent to the curricula but also think about and use it pedagogically. Teachers must conceptualize what it means to "understand mathematics" rather than just to "do, or to memorize mathematics" (Ball, 1996, p. 506).

Ball (1996) proposed that innovative curricula might be written with teacher learning in mind. A curriculum could "offer teachers mathematical ideas and ways to represent them . . . they can offer alternate tasks and discuss their relative disadvantages and pitfalls" (p. 506). While curricula have been created with these goals in mind, how teachers interpret and use them is still largely unexplored (Ball, 1996).

With the implementation of these new curricula, there now exists a fertile place to look at the nature of the changes that occur in a teacher's practice as they adopt this curricula. Teachers can learn from and make changes in their practice consistent with the reform (e.g. Simon & Schifter, 1991; Schifter & Fosnot, 1993). In the Purdue Problem-Centered Mathematics project, Wood, Cobb, and Yackel (1991) documented the vital relationship between teacher learning and pedagogical practice. It was Lampert's (1985) opinion that the relationship between the contiguous yet often contradictory responsibilities that make up a teachers practice lead to conceptual paradoxes. The very attempt to solve these pedagogical problems in turn lead to practical dilemmas (Lampert, 1985). But, is it these dilemmas that result in teacher learning?

Wood and her colleagues (1991) supported this very conjecture. What the project teacher learned resulted out of reflection on and resolution of the dilemmas which occurred in her second grade classroom. According to Smith (2000), the daily activity of a teacher to engage students in thoughtful and productive mathematical tasks produces a struggle which in turn changes the teacher's "perspective on what it means to teach and learn mathematics and be successful doing so" (p. 6). The occurrence of dilemmas is more likely to happen in a classroom where the teacher is attempting to implement reform as the traditional methods of instruction may be contrary or incompatible with reform-oriented methods (Ball, 1993). In Smith's opinion, these dilemmas may be more than just growing pangs in a teacher's effort to implement reform. These dilemmas may in fact be "springboards for teacher learning" (Smith, 2000). The resolution of the dissonance caused by dilemmas in a teacher's practice is a source of learning and may ultimately results in some sort of revision of a teacher's practice.

But what is it in the curriculum or the nature of support that initiates the dissonance which causes these dilemmas? In the case of Mrs. Oublier, Cohen (1991) found that it was the

policy set out by the district in conjunction with a new curriculum that led to the reform in this second grade classroom. Yet the nature of this reform was superficial. Cohen found that though Mrs. Oublier had incorporated elements of reform such as students seated in groups, the use of manipulatives, and an innovative curriculum, the pedagogical structure of her classroom was largely traditional. The classes presented "an extraordinary mélange of traditional and novel approaches to math instruction" (p. 328). In the case of Mrs. Oublier, the tensions or dilemmas in her practice were only evident to the researcher; they did not provide a sense of disequilibrium for her. The question remains: What is it that supports teachers in their efforts toward reform that would make these dilemmas salient so that an instructional fabric consistent with reform might cover the classroom practices implemented by teachers?

In the last few years the National Science Foundation has funded many projects aimed at supporting teachers in reconceptualizing their mathematics teaching. These teacher development projects are seen as vehicles that will assist them in the transition from traditional to reform-oriented teaching. They address issues of mathematics and its teaching and act as support for teachers' efforts to reform their practice. With the implementation of a new curriculum, each teacher interprets, relates and adjusts the intended curriculum to her or his classroom (Schmidt, McKnight, Valverde, Houang, & Wiley, 1997). This interpretation is rooted in a teacher's experiences such as being a math learner in a traditional classroom or reflecting on a recent experience of reform-oriented activities. Teacher development programs directly related to the intended curriculum might have a powerful impact on the extent to which key ideas and activities of this curriculum are utilized in class. But again, little is known about the relationship that develops between the teacher's learning in a teacher development project and her implementation of the curriculum.

Smith (2000) recognized that if we accept "dilemma-induced" conflicts as a catalyst for learning then we must understand more about how these dilemmas occur as well as, the nature of support that can be provided for teachers in order to contribute to the change process. Ball (1993) recognized this need to learn more about the crucial resources for "managing the dilemmas of mathematical pedagogy" (p. 395). The understanding of the internal and external influences that contribute to teacher reform influence the design of future environments that may support this change.

The purpose of the study reported herein was two-fold: (a) to explore the relationship that develops between a teacher's learning in a teacher development project and her implementation of an innovative curriculum as it may influence the resolution of dilemmas that arise as she attempts to reform her practice and (b) to identify features of the teacher development project and the curriculum that appear to impact the teacher's practice. This study builds on the work of Wood et al. (1991) by looking not only at the influence of reform-oriented curriculum materials in their ability to help a teacher reform her practice, but also acknowledging the relationship those materials and teacher development projects have as a possible influence on a teacher's practice. This study also builds on the work of Smith (2000) by contributing to current literature an understanding of the type of support that makes a difference in encouraging teacher change.

Method

Participant

This study focused on Maria Joseph (a pseudonym), a second grade teacher in a public school in central Pennsylvania. Mrs. Joseph was selected as the subject of this study for several reasons. First, as part of her participation in the Mathematics Teacher Development (MTD) Project (see details below), Maria implemented Investigations in Number, Data, and Space

(Investigations) (TERC, 1998) for the first time. Observations during initial implementation can help to answer questions regarding the influence of the MTD project on the teacher's decision and sense making regarding the curriculum. Secondly, Maria was using Investigations as the main source of the implemented curriculum rather than as a supplement. The Investigations curriculum is designed as a comprehensive series of related units that include appropriate mathematics for each grade level as proposed by the Standards (TERC, 1998). In addition, both the style and the methods of instruction in Investigations follow recommendations proposed by the Standards (NCTM, 1989). Because of these characteristics, her use of the curriculum as the main source of instruction may reveal her willingness to employ and possibly change her current practices in order to follow the intended curriculum (TERC, 1998). Thirdly, Maria was a veteran of ten years at Center County Public School. Most first and second-year teachers are just familiarizing themselves with and becoming accustomed to the curriculum set forth by the district. A veteran is assumed to implement the curriculum in a way that reflects how she perceives Investigations to meet the students' needs and the district's requirements. As a veteran, Maria has well established routines for teaching mathematics and managing her classroom. Maria was typical of many elementary school teachers in terms of her mathematics education, certification and the traditional approach she took toward teaching math prior to her participation in the Project. Maria took as reform-oriented that which she has learned through her participation in the MTD Project as well as those guidelines set forth by the Standards (NCTM, 1989).

Maria had been selected to participate in this study out of the MTD Project, directed by Dr. Martin Simon and Dr. Ron Tzur at The Pennsylvania State University. The MTD Project provided a 5-semester instructional program to a group of both practicing and prospective teachers. The instructional program focused on the continued development of the participants'

understanding of children's mathematical thinking and its development, the participants' own mathematical thinking, and a knowledge of ways to promote students' understanding of mathematical ideas (Heinz, Kinzel, Simon & Tzur, 1997).

Data

Three data sets occurring on the first, fourth and fifth weeks of the study were collected. Each set consisted of a preliminary interview regarding the episode to be observed, the observed episode, an interview about the observed lesson and in anticipation of the episode to follow, the observation of a second episode with its concluding interview. In addition, the participant was interviewed prior to those five weeks to obtain background information. The interviews conducted were informal as well as semi-structured (Merriam, 1998). While the semi-structured interview is guided by a list of questions to be explored, neither the exact wording nor order of the questions is determined ahead of time. This allowed for flexibility as a pre-set list of questions would not allow for the storytelling so crucial to the interview (Merriam, 1998; Stake, 1995). Informal interviews occurred unscheduled and included phone conversations as well as conversations in passing. Each audio-recorded interview and video-taped classroom episode was transcribed verbatim by the researcher.

A three-interview series as outlined by Dolbeare and Schuman (as cited in Seidman, 1991) was used. The first interview serves to establish the context for the participant's experience. The second interview is used for reconstruction of the experience within the context in which it occurs. A third interview encourages the participant to reflect on the meaning that the experience holds for her. For the purpose of this study, the series was expanded to include three sets of the three-interview series which were interspersed with observations in order to provide context for these interviews. As emphasized by Seidman (1991), a participant's behavior

becomes meaningful only when placed within the context of their lives; without this context, the possibilities of exploring the meaning of the experience are greatly diminished. In this sense, the interviews prior to the observations were used to discuss how the participant prepared for the class to be observed, what she anticipated concerning student learning, and what she did to make sense of the curriculum. The interviews immediately following the observations were used to gain insight into the reasoning behind the actions and choices made during the observed session. This debriefing allowed for the clarification of any questions that arose for the researcher during the observed experience.

The observations were videotaped and analyzed in conjunction with field notes and the interviews. A researcher's journal was kept with entries recorded daily regarding working hypotheses and progressions of data analysis. For example, entries were made regarding an observed lesson and were the basis upon which questions were outlined for the following interview. As working hypotheses emerged, interview questions were designed to explore these hypotheses further. Visits to the research site allowed for observations of the participant (Merriam, 1998) and provided a context for the interviews so that the participant's response could be grounded in a specific lesson set within a specific unit. Seidman (1991) stated that "what an observer understands as a result of an observation may not be at all consistent with how the [participant] views his own behavior" (p.3). It is for this reason that an interview was conducted immediately following each observation in order to clarify and further understand the observed phenomenon (Seidman, 1991; Merriam, 1988). It follows that in an effort to inform the study regarding the experiences Maria had in the MTD Project, observations were made while attending the classes during the semester concurrent with the study.

Analysis

The analysis proceeded in three phases. In phase one, raw data were coded for areas of the curriculum perceived by the teacher to assist her in planning and implementing of the curriculum. In phase two, areas were identified as dilemmas or conflicts between reform-oriented teaching and the teacher's traditional practice. In phase three classroom observations and interviews were analyzed with special attention given to possible evidence that might suggest a developing relationship between the curriculum and the teacher's professional development through the MTD project. The researcher then looked at the ways in which resolutions to these dilemmas manifested themselves in the teacher's verbal accounts and actual classroom instruction. The sources for these resolutions where evident were attributed to the curriculum, the professional development experiences, or both where applicable. Where no resolution was evident as of yet, the researcher tried to account for this lack of resolution. The researcher then worked to validate key observations and replicate or triangulate findings by gathering additional data.

Results

In the following sections, a description of Maria's characterization of the teaching she did in her early years will be outlined. Immediately following, the evolution that had ensued in Maria's teaching and what she perceived to have influenced that evolution will be described. These descriptions will serve as a backdrop for understanding the dilemmas that are evident in Maria's practice as she continued to use the Investigations curriculum.

The Early Years: A Growing Dissatisfaction with Traditional Practice

Maria had been teaching second grade in the same elementary school for ten years. She presented a view of her early teaching, which suggested a traditional approach. When asked to describe her practice she began:

> When I first started teaching I went to the other second grade teachers and said "What are you doing, can I do it too? Do you mind?" and I basically picked their brains all year long. Whatever they were doing, is what I was doing. This was ten years ago, we did a lot more workbooks than we do now, a lot of paper-pencil activities, we never had textbooks [but] we used to have a student workbook for math that you would flip around and do different pages and things. I remember myself as being much more time structured. I had twenty minutes...that was it, this group is done....we'll finish tomorrow. [later she adds: We had] a lot of timed tests memorizing math facts. We gave them these little short sheets of twenty problems and we would give them incentives for learning them all.

Maria's early teaching seemed rather typical of what the NCTM Standards describe as traditional teaching. Her view of mathematics seemed to be that of an isolated activity which occurs during a specified length of time geared by what others did rather than by what her students needed. The past ten years of Maria's teaching had been driven by a highly traditional influence: an emphasis on memorization and many paper-pencil tasks. This is further evidenced by her choice in methods of assessment: "What I did for assessment, which is similar to what we did in the classroom [were] the multiple choice, fill in the bubble, 90% right test." Therefore, Maria's views of assessment seemed to be focused on the answer. The fact that the tests were multiple choice in nature may indicate that little or no attention was given to the way her students solved

the problems. These elements: timed-tests with a focus on memorization, the use of many paper-pencil tasks, and the focus of her curriculum on what she would do or others were doing led to the characterization of her teaching as highly traditional.

Maria recalled the way in which her practice evolved. These data indicate how participation in a Master's program (prior to the MTD Project) may have been an influence on this evolution.

> The first year was just surviving and the second year was just "ok this is the way I did it last year, I don't know if I want to do it that way" and trying to find another way to do it. I would say that maybe the first three years I was much more the same than any of the seven years after that. The third year ...[w]e did centers every day, five days a week, two week rotation.... I started eliminating some of the workbook stuff....Part of it may have been my master's [and] trying to look at the way I teach.

By her third year of teaching, Maria began to add reform-oriented aspects to her method of instruction. The addition of centers and a reduction of paper-pencil tasks perhaps indicate an effort to try something different with her teaching as her participation in a master's program had brought about a reflection into the way she teaches. The very notion that Maria began to evaluate her teaching practice shows that she was developing as a reflective teacher. The addition of centers in her practice may indicate that upon reflection she became dissatisfied with some aspects of her teaching and thus added centers in order to improve that practice.

In keeping with her reflective nature, Maria again examined her practice and evaluated the success of center implementation. She conceded that perhaps those aspects of reform-oriented teaching were not as effective as they could have been and commented: "The centers

were more teacher directed [said with disappointment]. A station was me, and a station was her [points to the pre-student teacher in the room], and a station was [the student] by herself." Maria explained that the centers were a teacher-directed small group activity. Dissatisfied with traditional teaching, she proceeded to incorporate centers into her daily routine, but was once again disappointed with the outcome. The centers, or stations as Maria called them, though an activity characteristic of reform-oriented teaching, were implemented in a traditional manner.

Another element of reform that Maria began to incorporate into her classroom practice was the use of manipulatives. She recalls "gluing beans on bean sticks and cutting out raindrops for puddles....We were starting to explore some [with the attitude] "Let's make sense of manipulatives," but looking back I still don't think that [I] was maybe as effective as [I] could have been."

Although she added the use of manipulatives to her practice after reflecting on the success of the centers, Maria was again dissatisfied. She recognized that she may not have been using the manipulatives as effectively as she would have liked. Both activities, beans on bean sticks and raindrops in puddles, could be used as reform-oriented activities aimed at developing a conceptual understanding of place value and composite units. However, Maria did not believe that her efforts were effective in this capacity. She was working toward reforming her traditional practice by incorporating elements of reform-oriented teaching, but did not see the results she sought.

Regarding the evolution of her practice, Maria continued to explore this growing dissatisfaction and hoped that her participation in the MTD Project would help her accomplish the results for which she was looking. Maria recalled that during the three years prior to joining the MTD Project

> [She had] been dissatisfied with the way that [she] had been teaching math because...there were just kids that weren't getting it. What else can I do to help these kiddos? And someone told me about the project and I said, 'Oh. Okay I'll sign up for that and see how it goes.'

Though Maria had continuously changed her practice over the past ten years, she had not developed into the practicing mathematics teacher she had hoped to become. She recalled a continuous dissatisfaction that although centers and manipulatives were added into her teaching practice, some of her students were still not understanding the mathematics. Therein lies the shift in her focus. In early years the focus was solely on the outcomes of tests; later it shifted more towards her students' understanding of mathematics. What began as a very directed practice characterized by worksheets and timed tests, subsequently led to a disenchantment with a current teaching practice. It was this new focus and dissatisfaction that was seen as the main reason for her decision to participate in the MTD Project and the eventual implementation of the Investigations curriculum.

Maria's Participation in the Mathematics Teacher Development Project

At the onset of this study, Maria was in her fifth semester in the MTD Project but memories of her first year as a participant were still fresh in her mind. She recalled:

> We did a lot of math for ourselves and it was very frustrating and I hated it. The second semester we started watching some videotapes [of children doing math] and I said oh, I can deal with this and we started doing some interviewing.

Her initial participation in the MTD project was one filled with much tension and frustration for she did not know the math; it was not something that she could do or explain. It seems to have been a struggle for Maria to become a learner of mathematics. However, as indicated in a

conversation after one of the Project classes, she expressed that it was a useful experience in her eyes as she could now sympathize with the struggles her students were going through. Moreover, she recognized the importance of this struggle for her own students' learning.

By the fifth semester of the project, it was evident that Maria was no longer frustrated but instead valued the influence that the Project class had on her teaching. Her consistent reference to the learning of mathematics and mathematics pedagogy throughout our interviews illustrated this notion. During the course of this study, Maria demonstrated many aspects of her teaching that resulted from her participation in the MTD Project, one of which was the implementation of the Investigations curriculum. The following presents a brief history of her participation in the MTD Project, and highlights those aspects of the project that Maria saw as pivotal in her development as a math educator.

The Relationship between the Mathematics Teacher Development Project and Investigations: A Means to Resolve Practical Dilemmas

This section describes the elements in Investigations and in the MTD Project that seem to have influenced the evolution of Maria's practice, with a focus on the way in which Maria believes that the relationship between the two have helped her reform her practice through the resolution of practical dilemmas. Three particular dilemmas are highlighted: The Teacher Decision-Making Dilemma, the Assessment Dilemma, and the Classroom Organization Dilemma. Each dilemma is presented and the course of its resolution is identified and attributed to elements of the MTD Project, Investigations, or both where applicable.

The Teacher Decision-Making Dilemma

Influence of the MTD Project. Maria recalled an experience in the MTD Project where one of her responsibilities for the class was to interview a student or group of students on addition and subtraction, to determine the nature of student understanding:

> [We had to] look...at the ways children think...[in order to] understand the processes they are going through [in] their heads...what a child understands about the way they are carrying and the way they are borrowing.

In these MTD class activities, Maria had to reflect on a student's understanding of a particular math concept. Though there was no exploration of what Maria understood from this experience occurred at the time of the interviews, it was concluded from class observations that Maria takes as central the issue of place value in the learning of double-column addition. She eliminated the emphasis on the procedure and recognized the important focus on the development of a conceptual understanding of these operations. In the MTD class, Maria was able to reflect on a student's actions and explain what a student knew and understood.

Maria had incorporated this practice of interviewing and listening to students into her teaching style. This can be seen in the following segment where Maria and her pre-student teacher considered what a student knew in order to determine how they would proceed with the next day's lesson. The Student teacher begins: ("Pre" stands for Pre-Student Teacher):

> Pre: He was trying to make fifteen cents using ...what he was getting at was the ten pennies and the one nickel. But he kept saying I need ten dimes. So...I don't know if any of you saw me go up and get the dimes box and [I] gave him ten dimes so he counted them. He counted them as tens. But whenever he got to that nickel he was...like "Wait, [pauses] that is not

right." So then he took the pennies and started counting them. So again he counted those as tens and then somebody in the group said "Wait...those are ones."

Maria: So what does he understand and know? [researcher's emphasis]

Pre: That is a good question. He has a hard time distinguishing between the coins. He can't jump from counting a dime to counting a nickel to counting a penny. He has to have all the same. Like if he just had the fifteen pennies he would be fine but once you give him two different coins, three different coins forget it.

Maria: So he can't go back and forth between units that are different. And I agree with you that that is a step past [another student] who is still working on "What is it? and How much is it worth?" And if I have five of these am I counting ones, fives, or tens?

Pre: So what does [this student] need to do?

Maria: That actually is a very hard point. In my opinion, it is almost harder than teaching [the other student] because he can at least do the rote practice: this is a penny, this is dime....count....[This student] can do them each within its own pile...I think, it is almost a shift in their thinking. I suspect that he might not get this until at least February or March when we have some more regrouping games because that is when I think kids tend to make the connection between "well wait a second this is like that red chip and the yellow chip. This is worth three of those."

Maria took her experience of interviewing from the MTD project and began to use it in her practice to determine the next steps she would take with her students. It is an action she does in reflection of the day's lesson and in anticipation of the lesson to follow. As Maria reflected in the aforementioned teaching episode, she focused on individual student learning. She and her pre-student teacher engaged in a conversation that compared two students in the classroom. They explored what it was that they would do in light of the conclusions realized regarding the students' understanding of working with coins. Earlier in her career, Maria designed her teaching based on what others were doing. The next day's lesson was usually determined by what her peers were doing and later by what was outlined in the district curriculum (e.g. the next day's work was determined by the next topic in the curriculum guide). In contrast, Maria's focus in this case was on student understanding in order to determine her next lesson. Maria had continued to reflect on her practice and recognized that it was essential to include student understanding in these reflections.

As observed, Maria's conversation with the pre-student teacher is consistent with the Project classes in which the teachers would evaluate vignettes of students doing mathematics to determine what they knew and where the teacher would go next. The class would discuss tasks that might be used to help the student draw further conclusions about the mathematical concept. She found such exploration of students' understandings to be fundamental in the planning of subsequent lessons. In the MTD Project she learned that by targeting her reflections on what the student knew she could focus on how to gear her teaching to further that understanding. It was this practice that she had applied to her own teaching. This example of reflection on her teaching is not an isolated incident. Oftentimes during the course of an interview the evolution of a lesson

plan based on the observations Maria made during the course of teaching the lesson was witnessed first hand.

A recurring goal for Maria was the continual focus on the students' thinking. When reflecting on a particular lesson she said that she tries to "think about what [she is] teaching and what [the students] are learning and not learning." On numerous occasions during the interviews, she expressed the need to dedicate more time to this component of her teaching. One such instance noted below occurred immediately after an observed lesson:

> Sometimes I find myself thinking, okay they are all working I can go and get this other thing that I have to do....I forget to just sit down and kid watch...like I did today; I was only with three kids.

When compared with images seen from Maria's account of her early years, we begin to observe the juxtaposition of two teaching styles that emerge in Maria's attempt to reform her teaching. The elements that linger from the traditional method of teaching to which she was previously accustomed are in conflict with the reform-oriented practice now implemented. In particular, as seen in the previous excerpt, we see how her recognition of the need to observe students contrasts with the traditional method of seeking feedback on student progress through the use of a worksheet or test. This contrast illustrates the first element of the Teacher Decision-Making Dilemma.

Influence of Investigations. This sort of reflection on student understanding seen to modify Maria's decision-making in the classroom is also encouraged by the curriculum. The Investigations curriculum provides sections for the development of teacher knowledge known as "Teacher Notes," "Dialogue Boxes," and "Teacher Checkpoints." These sections are a means through which to "help teachers think in new ways about mathematics and about their students'

mathematical thinking processes" (TERC 1994, p. I-7). The Teacher Notes are filled with practical information about the mathematics embedded in the lesson and about how students learn. The Dialogue Boxes contain sample dialogues that demonstrate how students "will typically express their mathematical ideas" and are designed to help the teacher prepare for her own class discussions (TERC, 1994 p. I-7).

> [Teacher Checkpoints] offer a time to 'check in' with individual students, watch them at work and ask questions that illuminate how they are thinking.... Teacher Checkpoints also give [the teacher] a chance to pause in the teaching sequence and reflect on how [her] class is doing overall. (TERC, 1994 p. I-10)

When reading the curriculum, Maria focused on the section labeled "Observing the Students" in each investigation. This section is a source of sample questions embedded in the Teacher Checkpoints which can be used to assess student progress and mathematical understanding. In the following excerpt we see these sections as direct influences on the Teacher Decision-Making dilemma:

> The use of the curriculum has affected my teaching because it is easier for [me] to remember to think that way [reform-oriented] and to teach that way because a lot of those reminders are in Investigations whereas last year, we had to remember that on our own. [Later] I was just going to say that one of my goals is to read those questions over ahead of time and remember [to] look for them.

Maria believed that this section of the curriculum helped focus her interpretations of student thinking. Maria found them quite useful as they served to reinforce that which she had come to learn about students' thinking during the MTD project. They also served as reminders of the kinds of questions and discussion that needed to occur in the classroom.

It is clear that Maria recognized the importance of reflecting on student thinking in order to decide on the next-steps of her lesson and used the curriculum to help her in these efforts. However, as observed in her teaching episodes, Maria was not yet flexible with these interpretations. Maria was at the beginning of a significant path of development in being able to reflect on student thinking during her lessons and to make decisions accordingly. She was quite able to reflect on issues of student learning prior to and immediately following the lesson, but during the lesson this did not occur as easily.

It follows, that Maria's reflection on her students' learning affects the way she reflected on her own math learning when implementing a lesson. When teaching the addition and subtraction portion of the Investigations, Maria recalled paying close attention to the series of "Teacher Notes" and "Dialogue Boxes" regarding the mathematics embedded in that unit. Maria recognized the need for a personal understanding of the mathematics contained in the curriculum prior to the implementation of the lesson. She commented:

> A couple of [the Teacher Notes and Dialogue Boxes] I really use are on combining and separating. I know I am going to have to re-read that because that is a different way of looking at addition and subtraction. What I have found from those notes is anything that I have not encountered before, I tend to have to stop and go over and read it a couple of times and say "Okay, Oh! I get it. I see what they are talking about."

There were several occasions during which Maria referred back to those "Teacher Notes" and "Dialogue Boxes" in order to inform her teaching during an observed episode. She referred back to the objective and goals of the lesson or focused on the questions to use while she observed the students. In essence, Maria used the curriculum to promote her thinking of

mathematics and to remind her of the mathematics found in the lesson. Maria admitted that the Teacher Notes in the sessions on "Combining and Separating" found in the Investigations unit Coins, Coupons and Combinations (Russell & Economopoulos, 1998) helped her to think about addition and subtraction situations as she had not done in her ten years of teaching prior to the implementation of the unit.

Both the Investigations and the MTD Project have influenced Maria's teaching in mutually connected ways. What she learned in the MTD Project was implemented in the classroom and reinforced by the curriculum. In particular, the interplay between the curriculum and Maria's experiences in the MTD Project influenced her Decision-Making in the form of attention given to and reflection on student thinking.

Assessment Dilemma

The evolution of Maria's ideas about assessment was the second dilemma influenced by the relationship between Investigations and the MTD Project. Part of the assignments in the MTD project involved the reading of and reflection on John A. Van de Walle's Elementary and Middle School Mathematics (1998). Maria commented on how these readings had an impact on her decisions about assessment:

> Both Investigations and the MTD project, including the reading of Van de Walle push the explaining [of] your thoughts and your thinking so that you are not just rotely doing what you have been trained [to do]. And I think if that component of the program wasn't in there I wouldn't bother.... [One of my] big...goals is to have them automatically have that second part [the reasoning behind their solution] spit out of their mouth and what I am hoping is that when they get to

> third grade and they say to their teacher, "Well what did you get for an answer? Well I got this **because** I took this, this, and this,..."

In contrast to Maria's description of her practice during her early years where the traditional emphasis of assessment was on memorization, her practice had evolved to include more reform-oriented aspects of assessment; namely, the student's ability to understand and reason about math concepts. Maria recognized that as the name "Investigations" implies, a great deal of emphasis should be placed on the student's ability to explain her answers. In part, this recognition seems to grow out of her learning from the MTD Project. Investigations also encouraged and emphasized this focus on student thinking.

Maria was explicitly aware of the role that the curriculum played in changing her perspective and practice. For example, when asked to contrast her practice this year with that of years past, she claimed:

> This curriculum focuses more on having the kids think. So I think that it has affected my teaching because it is easier for [me] to remember to think that way and to teach that way [reform-oriented] because a lot of those reminders are in Investigations... reminders of what you [as the teacher] are supposed to be looking for.

This new focus of listening to children in order to ascertain what it is that they know, is an explicit goal of the curriculum. For example, part of any task inherent to the lesson on "Combining and Separating Situations" (Russell & Economopoulos, 1998) is that a student explain her answer so that someone else can understand it. Maria made this explicit by requiring that students check with her for approval on the clarity of their explanations before they were finished. This is also evident in the curriculum because most worksheets and activities include a space specifically designated for students to reflect on and record their thinking or solution

strategy. Thus, the interplay between the MTD Project activities and the use of Investigations changed Maria's perspective on what was considered valuable when doing mathematics. In turn, this new perspective contributed to a change in her practice with regard to the evaluation of student answers. This was evident in her instructions to the class regarding their assignment: "To be honest, I really don't care what the answer is—I just want to know how you solved it. The only wrong answer is not putting anything down [meaning any explanation]."

Besides the obvious focus on explanation, another element of assessment important to Maria was the flexibility of solution strategies. This focus contrasts with her early teaching where she used "short sheets of twenty problems" and focused primarily on answers (e.g. "90% right, multiple choice test").

> It is really hard. Sometimes I want to say: "do them [the story problems] all" and I know that that gets to be redundant. They don't need to do them all, but I want to see what they are thinking. Of course I can see what they are thinking the first time through not the third. But, I think the Investigations [curriculum asks]...to have them just do a couple not to do them all.

Tension was again evident between her traditional background and the practice she wanted to reform due to influence of Investigations. Maria was accustomed to having students complete all of the problems in order to gain a whole picture of her students' knowledge. However, Investigations emphasizes not quantity but quality. The curriculum is designed so that students may explain their work and reflect on it, rather than complete extensive worksheets. Maria recognized this objective and though contrary to her traditional background, she resolved this dilemma on the recommendation of the curriculum.

Classroom Organization Dilemma

A similar solution to the dilemma stemmed from the tensions of classroom organization. The influence of the inter-play between Investigations and the Project was evident in Maria's views on grouping students compared to individual work. When Maria was observed interacting with her students during a group math activity, it became evident that the individuals in each group were expected to help each other in both interpreting and solving the task. In the interview immediately following the observation she commented about this practice:

> [Investigations was] talking about working by themselves,...in pairs, or... in groups. Van de Walle had suggested in the problem solving chapter ... [to] almost always hav[e] [your students] work in pairs or in groups to get them to bounce ideas off of each other. It just hasn't sunk into me that it is something that I should be doing more regularly. [My] concern...is that depending on how we put [them in groups]...it could just be one person doing all of the work and the other one just copying frantically down what they have. Pairs in here is so hard. It is a stressful activity, making pairs. [Later.] And [it] is a different way of teaching than I have ever done before...but I think that Van de Walle is saying that they will get past that and they will get to the point where... they have to work together on it. And I went. . . hum? Okay? I'll try it.

Maria was not accustomed to having her students work in groups. Moreover, this seemed to be in conflict with her traditional view of individual accountability. Yet, the curriculum of readings and discussions for the Project fostered this type of learning situation. Though tension was evident between the two extreme poles of her teaching practices, she was willing to have the students work in pairs because it was reinforced in both the curriculum and in the Project.

Therefore she bridged beyond a traditional scope to a more inclusive reformed atmosphere. This relationship encouraged the resolution of the Classroom Organization Dilemma.

Student Interactions: A Lingering Dilemma

The previous sections show how Maria's teaching was evolving toward reform-oriented practice. However, this change embodied tensions and dilemmas whose resolution seemed to occur as a result of what was learned in the MTD Project and the incorporation of the curriculum. Yet there were tensions in Maria's teaching which had not yet been resolved. In particular, observations of specific tensions existed while she interacted with her students.

When Maria was teaching an investigation found in Coins, Coupons, and Combinations (Russell & Economopoulos, 1998), the lesson involved three "Choice" activities that were targeted at becoming familiar with coin values and building equivalent relationships (Russell & Economopoulos, 1998). The first activity, "Ways to make twenty-five cents," involved the students in a systematic exploration of finding possible combinations of a nickel, dime and penny that totaled twenty-five cents. In the second activity, "Matching Coins and Coupons," the students selected a coupon (say for fifty-five cents) and made an equivalent combination of coins (e.g. five dimes and a nickel). The third activity, "Collect Fifty Cents," involved rolling a number cube, selecting coins equal to that value and trading when possible in order to arrive at a quantity of fifty cents. Students participated in these activities over the course of three days.

Though the main objective of the three Choice Activities was to become familiar with coin combinations and equivalencies, Maria's implementation of the activities highlighted a dilemma for her. Maria allowed students who appeared quite proficient in the identification of and the equivalencies of coins to participate in the activity, but placed students not having achieved a considerable level of mastery in a separate group. Moreover, these students worked

with her paraprofessional on the rote identification of coins and the creation of quantities out of contexts. With respect to these students Maria claimed: "You just have to tell them and then get them to play with it." Here one assumes that the identification of the coins by value is conventional knowledge and must be told to the students. However, once those values are presented, it seems that a reform-oriented strategy would allow those students to have experiences with the coins that can foster the intended learning. The Choice Activities were meant to provide these experiences, yet, Maria did not allow the struggling kids to participate. The traditional approach of drill and practice seemed to resurface because she did not think that the curriculum could help these students. Maria did not see the potential that the task itself possessed in the development of a conceptual understanding of the relationships among the coins. In this case it appears the curriculum activities, originally thought of as a means to learn new ideas, were used for practice by students already familiar with the ideas. Herein lies the dilemma of student interactions.

In a later episode during the study, a similar situation was observed. Maria created the following problem for the class to solve in the context of the investigation on additive combinations:

> Our class and Mr. Duffy's class are going on a field trip together. We take 23 kids and 4 adults and Mr. Duffy takes 24 kids and 3 adults. If the bus holds 55 people, will there be enough room? How do you know?

The objective of the curriculum is to help students visualize the problem in any particular combining situation and to develop the ability to solve the problem and explain the solution strategy. In creating the modified problem above, Maria had personalized the situation to her class thereby indicating a sensitivity to her student's ability to understand the problem. However,

when two of her students encountered some difficulty, Maria concluded that both of them were "getting stuck on the fifty-five," and told them to "ignore the fifty-five. The fifty-five is a number that you will use for comparison once the problem has been solved." In doing so, Maria took a more traditional teacher directed approach rather than follow the objective of the curriculum to help the children visualize what was occurring in the problem.

During the follow-up interview to this episode Maria was hesitant to answer when questioned about the effectiveness of this choice. She said that the boys were headed down the "wrong path" and rather than allow them to continue on this trajectory, she made a "teacher decision" to answer their questions in this manner. Maria's choice indicated a dilemma rooted in the tensions between traditional and reform-oriented teaching. On one hand, Maria's enactment of the lesson did emphasize the explanation of the solution strategy as highlighted in the curriculum. On the other, she seemed to fall back on her old practice of procedures rather than on visualization while attempting to solve the problem. This short-cuts the student struggle. The curriculum suggests that the emphasis in problem solving is two-fold: to understand the structure of the problem, and to develop and explain strategies used to find a solution (Russell & Economopoulos, 1998). Maria's main emphasis was on the finding of a numerical answer as well as the explanation of the solution strategy. We do not see a focus on the major objective of the lesson which was to develop an understanding of combining and separating situations.

When looking at the nature of her interactions with students, the juxtaposition of traditional and reformed-oriented teaching becomes evident. Maria used reformed teaching strategies by having the students work to solve problems in context, in pairs, and with manipulatives. However, when a student was not successful with this approach, she seemed to fall back on her traditional way of teaching. This inconsistency could be due to the fact that

traditional teaching is the method of habit. She is not yet proficient and flexible enough to employ reform-oriented teaching in novel situations; those on which she has not yet reflected. When faced with a student who was struggling in a particular way not previously encountered, she relied on the methods upon which she was familiar. This was in direct alignment with the stage of Maria's development as a reform-oriented teacher. She reflected on reform-oriented practices in context (e.g. in class or while reading the curriculum to plan a lesson). However, she still needed to develop her understanding and practice of reform-oriented teaching to a higher level at which she can use this way of teaching independently, in anticipation of student learning (and difficulties) and in reacting accordingly to whatever occurs in the classroom.

The tension between the two ways of teaching was also evident in Maria's comment: "I can't just do Investigations with them because my worry is that they won't get enough of the reinforcement and practice of the basic skills that they need." When students struggle, her interactions with them become more focused on mastery through a teacher directed approach. Perhaps these tendencies are lingering aspects of her traditional style; a style frequently related to the requirements of the district. In her mind, the learning and practice of basic skills was a separate objective from the curriculum rather than something that would be accomplished through the use of Investigations. This relationship highlights the tension that she believed to exist between the district requirements and the implementation of the curriculum.

In the following excerpt, Maria described her district as one that only provides a list of outcomes which must be met at each grade level.

> [T]his district is very, concept oriented. Because we don't have a textbook we have certain…I don't know if concept is the right word, certain outcomes, certain things that you have to cover. No matter how you teach you have to make sure

that you cover these certain things, and you must prove that you have covered them.

In light of her characterization of district requirements, one can surmise that this might have been the root of some of the tensions that are evident in Maria's interaction with both the traditional and the reform oriented curriculum. Maria's perceptions of district requirements seemed to be pulling her in a direction more easily associated or accomplished through traditional teaching. The district required a hierarchical movement through an outcome-based curriculum. These requirements created a conflict in Maria, due to her serious intent to focus on her student's thinking.

Discussion

This study examined elements that helped to support a teacher in her efforts to reform her practice. In particular, this study focused on the relationship that develops between the teacher's learning in a teacher development project and her implementation of an innovative curricula. This study highlights tensions that arose for the teacher as she struggled to make sense of her own learning in the project and adopt reform-oriented ways of teaching that markedly deviated from the traditional ways she used to teach. These tensions led to three dilemmas which can be traced through the teacher's practice: the Teacher Decision-Making Dilemma, the Assessment Dilemma, and the Classroom Organization Dilemma. The resolution of these dilemmas occurred largely because of the relationship that the teacher saw between what she learned in the teacher development project and the innovative curriculum that she was implementing in her classroom. Because of this relationship, the teacher felt that she could take risks in resolving these dilemmas and made significant changes in her teaching practice; particularly in her method of assessment,

the focus of her lessons, and the extent to which she used grouping as a means to engage students in problem solving. A practice previously focused on the memorization of rules and procedures, became one that focused on the students' development of solution strategies and conceptual understandings.

Initially, Maria incorporated the old with the new to create a mix of reform-oriented and traditional pedagogy in her classroom. As in the case of Mrs. Oublier, Maria did not simply "shed [her]old ideas like a shabby coat and slip on something new" (Cohen, 1991, p. 339). It was only when the old and the new were incompatible that tensions arose and dilemmas needed to be resolved. These dilemmas were resolved because Maria could identify support for the changes she needed to make in both the curriculum and the Project. These changes may not have occurred had this support not been available. Not only were these dilemmas "springboards" for teacher learning as Smith (2000) indicated, but in the case of Maria the resolution of the dissonance caused by dilemmas in her practice was a source of learning that ultimately resulted in a revision of that practice.

These dilemmas resulted from what is viewed as two different tensions in the teacher's conceptions. Initially, the teacher experienced dissatisfaction because her old ways of teaching did not produce the desired understandings in her students. Later, upon implementation of reform-oriented strategies, the tension was between the newly learned ideas and experiences and the very traditional ways she was struggling to reform. Those traditional ways seemed to be the ones to which the teacher would frequently fall back when she conceived of conflicting goals or criteria to gauge progress. For example, when Maria found that some students were struggling with the lesson she used a traditional approach, instead of the problem-solving approach advocated in the curriculum.

Implications

The community of teacher educators expects teachers to implement change. The teachers are provided with the curricula needed to institute this change and the professional development that they would need to understand and implement the reform. However, as the teacher's case suggests, it is the teacher who must change her perspective and practice, and this change is neither simple nor unproblematic. Thus, this study highlights the need for more research on the developmental processes of teachers as they adjust their practice to include reform-oriented curricula and strategies (cf. Simon, & Tzur, in press; Simon, Tzur, Heinz, Kinzel, & Smith, 1998).

This study supports the view that there is a need to provide appropriate teacher development in conjunction with the implementation of new curricula. The possibilities for teachers to make changes in their practice greatly increase when the curriculum and the teacher development project mutually support each other. It seems that such combinations increase the teacher's willingness to take more risks and teach in ways that are radically different from what he or she is accustomed.

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